Draft Lessons Learned in Capturing Human Knowledge:
Cultural Issues, Knowledge Capture, and the Spiral Framework

Key Area: Capturing Knowledge of Humans and Organizations

Knowledge management (KM) provides many avenues of challenge and lessons learned for today's practitioners. This paper explores some of the contemporary challenges and lessons learned in association with three key areas: cultural issues specific to NASA; knowledge extraction and harnessing passion as the most powerful human interface; and using a spiral framework to understand the KM elements of the project.

NASA-Specific Cultural Considerations in KM

One of the challenges in recognizing KM issues specific to the NASA culture is that in many cases, valuable information that we would like to capture is tacit knowledge. Michael Polanyi (1966) , who coined the term, said, "We can know more that we can tell." And we do. Tacit knowledge is the result of our experiences and intuition, and is very difficult to codify. It is the valuable body of knowledge we instinctively know without necessarily being able to explain why.

One example of the tacit knowledge we encountered was realizing that NASA Technical Fellow (TF) Robert Kichak was very modest about his abilities and what he thought would be worthwhile to share. He graciously deflected our attention to others on his team; they were indeed a talented group. Bob, however, seemed unaware of his own brilliance at recognizing and bringing out the best in others, especially members of his technical discipline team (TDT).

While he finally did share many of his professional successes, lessons learned and insightful stories, the tacit knowledge he employed in putting the talents of others to work was much more difficult for our team to capture, and we captured much less of it than we would have liked.

With TF Hank Rotter, we experienced a number of opportunities in which he shared tacit knowledge. He recounted involvement with particularly sensitive briefings that were held with astronauts relative to the use and design of toilets in space. His anecdotal accounts demonstrated the importance of providing the proper environment for astronauts to tell their stories, despite their having become accustomed to being pricked and prodded throughout their career.

In another case, Hank had queried nozzle experts for advice on an engineering problem with water dump nozzles and received no feedback. One day he noticed some sandblasters working outside his office. On a whim, he approached them and asked about the engineering problem he was attempting to solve, and they suggested a solution. This was not a scientific approach, but a hunch that the sandblasters might be able to comment "craftsman to craftsman." He was innovative enough to spot similarities between the two applications and tweaked the sandblasters' suggestion to fit his engineering problem with the water dump nozzles quite successfully.

Through our many NESC Academy knowledge capture experiences, we have learned that every TF presents new KM challenges. We have discovered that no one formula works every time with these revered scientists and engineers. We negotiate different solutions with each one concerning objectives, their and their staff's availability, the number of individuals to be interviewed, the nature and depth of materials to be included in the online precourse, locations of interviews, course deliveries, and many more considerations.

Certainly we have learned that as cordial as all of these engineers and scientist are, they do not suffer fools gladly. We have had to ensure that our knowledge capture and support staff are at the top of their game before unleashing them on the TFs and/or their staff. We have also learned that, where there are options for flexibility, our staff needs to welcome them with open arms. These engineers and scientist are in great demand and we make more progress when we take advantage of "fall back" positions that permit schedule adjustments without incurring unreasonable additional costs.

As a contractor, we are contractually bound by our statement of work to identify how specific cultural issues enable engineers and scientists to survive and prosper within NASA. Identifying those issues is addressed through knowledge capture interviews and projected when TFs are provided a list of interview questions in advance. Naturally, the curriculum of the classroom and online courses incorporates this theme, allowing students to absorb career tips from some of the most successful performers in the organization. Some TFs discuss how to gain credibility. Others talk about the role of mentors and the necessity of keeping the big picture in mind.

One technique we've used successfully is identifying and augmenting our staff with subject matter experts who are familiar with NASA both from within and outside of its culture. They have assisted us in identifying cues to cultural elements that we might have otherwise missed. They have been very helpful with followup questions that helped extract tacit knowledge from the TFs. However, we still have a long way to go in this regard.

Another approach has been to focus the interviewee on what someone new to NASA needs to know to be successful. This is done by enforcing a value judgment; that is, requesting that the interviewee share what he or she perceives are three important pieces of advice for an engineer new to NASA. As always, our staff encourages the interviewee to share stories that reflect the unique NASA culture.

Knowledge Extraction

The Academy development team uses many techniques for knowledge extraction. The challenges posed by some of these techniques include how to:

- Capture key content from the interviewees in a very limited time.
- Convey to the TFs the value of their stories.
- Convince TFs that we are not trying to create a 101 version of their discipline.

- Train those conducting the interview to identify and capture tacit knowledge when possible.
- Determine the appropriate role of videotaping in the process.
- Help the TFs take the knowledge gathering seriously early in the process.
- Determine what is the most important information to be shared.
- Make the information available to the largest number of potential users.
- Determine the extent and frequency with which the interviewees are permitted/encouraged to review the draft captured materials.
- Identify and protect ITAR content without having a chilling effect of distribution.

There are a number of steps in the knowledge capture process:

1. Provide initial briefing by NESC Academy management to the TFs and their teams to help set expectations, encourage buy-in and establish ground rules and communication channels.
2. Identify internal subject matter experts (SMEs) for the individual discipline so that we can ensure technical accuracy and interpretation of the TF's data. The challenge is finding a knowledgeable generalist who can translate highly technical content to our team and conduct internal QA reviews of materials. This individual must be able to write well, feel comfortable participating in class delivery, and be tactful with all parties.
3. Conduct individual daily interviews of approximately one hour in length with the TF and his or her staff. These are conducted by Academy technical writers, an instructional designer, SME and sometimes the project manager (PM). These interviews are most often recorded and then transcribed.
4. Provide a list of questions to the TF and staff prior to videotaping a knowledge capture. The questions are designed to encourage sharing of both explicit and tacit knowledge and though they serve only as a starting point, almost always result in a more confident interviewee.
5. Conduct an onsite, multi-day data gathering session with the TF and selected team members. TheKM team, instructional designer (ID), internal SME, PM, Academy program director, and video team meet with and tape an extensive interview with the TF and selected team members. We have discovered that the formality accompanying a video shoot seems to help keep the TF and his or her team members focused. Some pieces of the interview may include a walk-through of a facility or lab. It may also include identifying and photographing models, samples, failed parts, legacy video, or published and unpublished documentation. Often we send still cameras with the video equipment to photograph high resolution images of parts or materials identified as being significant by the TF. Naturally, we also gather B-roll footage of place images to use within the final video product, if needed, to cover errors or deletions.
6. Conduct follow-up interviews via arrangements negotiated with the TF. Some hour-long interviews are held daily during the 50-day knowledge capture and analysis process; other interviews are longer in hours and may be spread over the 50 days. These interviews usually include a lead instructional designer and KM

team members, including technical writers, contract SME, and sometimes graphics or animation specialists. These sessions are recorded.

7. Transcribe and edit the interviews.
8. Digitize and upload videotaped interviews to the web site.
9. Analyze transcripts against the program objectives.
10. Develop a content outline for the platform course focused on lessons learned, NASA culture, and implications for future missions.

Lessons learned for Knowledge Extraction.

After conducting eight knowledge capture events, we have gathered several of our own lessons learned from extracting information from the TFs and their teams. Some examples are:

- Use videotape if possible, which encourages the TF and TDTs to take the effort seriously and helps fill gaps if problems occur with the course capture.
- Provide suggested questions to the TF ahead of time that explore and explain tacit and explicit knowledge.
- Schedule the TFs' time to the extent possible well in advance; be realistic with them in the earliest interviews about how much time and effort is required.
- Ask for copies of relevant documents, prototypes, models, samples, mistakes, defective materials, incident reports, diagrams, photos, videotapes, and relevant publications.
- Be clear that the TF should indicate if any of the content is ITAR-protected.

Meeting the Challenges of Knowledge Extraction

The following section describes how the NESC Academy met the exceptional challenges, especially as they relate to the three key areas above, in accomplishing its mission to "capture the lifetime experiences and knowledge of senior engineers and scientists, and to pass that information on to NASA's current and next-generation technical workforce." The Academy has been in operation for approximately two years and has successfully met its initial goals of:

1. Developing the NESC Academy Curriculum so that it enables veteran NASA engineers and scientists to pass their knowledge to current and future generations.

2. Developing the "Virtual Academy Institution."

We originally created three dedicated teams for each assigned TF and TDT. We created an environment in which three products were developed:

1. A Web site resource database and forum.
2. A classroom-delivered, technology-enhanced curriculum.
3. A self-paced, web-based delivery of the course.

Although constantly evolving, the NESC Academy has enjoyed a consistent branding throughout all of its materials and course deliveries. The Web site follows design elements created in the promotional efforts and mimics a university by providing services including: application processing, online course registration, student selection and admissions notification, library (including newly discovered materials, transcripts, video, still photos, etc.), physical plant (in our case, the logistics at university sites), security (software encryption, safety monitoring in the classroom, ITAR validation), faculty (technical fellows, TDT members, and guest lecturers), curriculum (complete instructor guides, participant's manuals, PowerPoint images, videos, field trips, guest speakers, etc.), transportation (logistics at campus locations), food services (logistics at university campus), recreation (reception on campus), registrar (automated transcripts), and online courses (available through the Web site 24/7 using video). We also provide help desk support and all computer services. Currently we do not provide counseling.

Course delivery, other than online, is accomplished at facilities located at colleges and university campuses around the country in locations near NASA centers. Classroom delivery is limited to about 30 people. There are typically from two to seven instructors, although one current class has 15.

We know anecdotally that individual graduates of the program have established small-scale communities of practice. The NESC Academy Web site has its own forum instituted to share information between instructors and students. It has met with a modest assessment of success. We are exploring other routes of sharing, including podcasting (we have prototyped this effort), NESC wikipedia, Academy alumni programs, and formalized communities of interest and practice.

One common chore of KM is the identification of individuals from which knowledge is to be captured. For our project, the management of the NASA Engineering and Safety Center (NESC) identified the original group of engineers and scientists who would become the focus of our knowledge capture. Certainly one of their concerns was losing the knowledge of this elite group of professionals through retirement or separation from the government. In fact, since the beginning of the Academy we have had one of our TFs retire from NASA within a few months after completing his knowledge capture and course offering.

We typically enjoy no more than a two-year window in which to schedule appointments with the selected engineers and scientists due to a rotation of assignments. These TFs are supported by a TDTs of talented engineers and other professionals who help them fulfill their multi-faceted duties. In practice, while the focus is on the experiences of the TF, from three to fifteen other members of the TF's team have been part of the formal capture and/or course capture. These TDT members have usually been identified through negotiation with the TF. To ensure quality we have learned that it is preferable to limit interviews to no more than six individuals from a single team within a three-month segment.

The Academy has used these teams to augment the important messages it would like to convey to NASA engineers new to the organization. Some of these adjunct experts have been captured on video individually, in their labs, or within a panel discussion. Some are regular NASA employees while others are professors, retirees, and contractors.

The Academy details lessons learned by sharing stories of how knowledge management provides unique lessons each time we move from one project to another in our capturing and sharing process.

Our project is concerned with two kinds of lessons learned: 1)The pragmatic one of implementing lessons about how to do the business of KM better, and 2) identifying and sharing the lessons the TFs and their staff learned in their years of experience with NASA.

After each knowledge capture and course delivery, our entire team of developers are asked to make recommendations for improvement. These recommendations are captured in an after-action report that is presented to the Academy program director. A meeting is held to discuss the various issues and the PM assigns staff to address any accepted recommendations that are within the scope of the contract. We have incorporated hundreds of recommendations based on lessons learned. She also identifies the potential cost of recommendations that are beyond scope.

For example, we adopted a precourse package as standard practice based on the first development team determining there was too much information to include in a three-day course. The team developed a precourse of read-ahead experiences and an examination to accompany the course. This allowed the TF the flexibility to move content into the precourse that would put all of the students on the same knowledge level about his story before coming to the class. This was not originally part of the plan; however, it worked very well and during the after-action review for that course it was decided to create a precourse for all of the courses.

Another example of the lessons learned passed on from the after-action review meetings is determining the graphics plan for the course during the analysis phase. Originally, we tried to develop as many animations as the TF and ID might suggest. During the first and second courses, we were receiving and downloading final animations the night before the class. The amount of time needed for developing and rendering the complex animations is extensive. This time element was discussed by the graphics team and based on both the explicit and tacit knowledge experiences it was determined a graphic strategy needed to be determined and used as the guide for developing complex 3-D and 2-D graphics, medium to simple graphics, and line graphics and charts. This allowed the team to have all of the graphics completed before course delivery.

The cost of the program was higher than originally expected or projected due to the many unknowns of setting up and implementing the Academy. To get the funding under control, a firm-fixed price was set for each course development effort. This allowed all parties concerned to control the desires for the course and make determinations about what was a “need to have” versus a “nice to have” for course development and delivery.

Lessons learned are a key part of the briefings given to the TFs and the focus of our analysis in the knowledge capture. At the highest level there are great similarities among the lessons learned. NASA engineers consistently emphasize the importance of sharing information with others.

A category of lessons learned that is of particular interest to our target audience is that which may apply to the missions to the moon and Mars. TFs are careful to point out things learned in the Apollo and earlier missions that had little value to the Shuttle or ISS, but which have great import for the long missions well outside Earth’s atmosphere.

Using A Spiral Framework to Understand the KM Elements of the Project

Since its inception in June 2005, the NESC Academy has implemented a successful knowledge management approach. This success is supported by multi-level evaluation results, anecdotal interviews with students, and an objective third-party evaluation that took place in December 2006. Data from these evaluations confirm the effectiveness of the current knowledge management approach; they also serve as a source of ideas for continuous improvement.

The easiest way to discuss the elements of KM within this program is through the vehicle of the spiral knowledge framework. The knowledge spiral, according to the Nonaka (1995) model (see Figure 1) proposes how tacit and explicit knowledge interact. Its function is to create knowledge within an organization. The four patterns suggested are socialization (tacit to tacit), externalization (tacit to explicit), combination (explicit to explicit) and internalization (explicit to tacit).

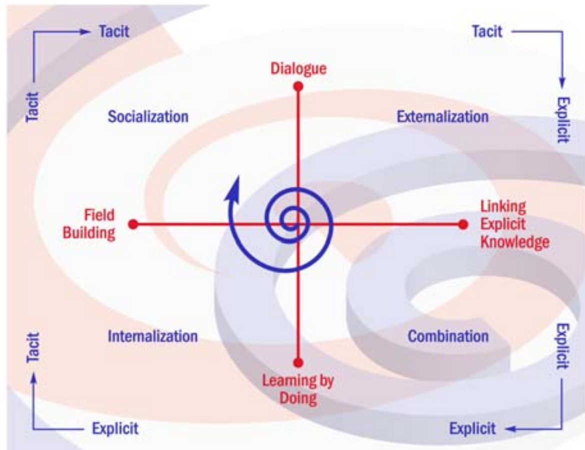

Figure 1
Spiral knowledge framework, Nonaka (1995)

The NESC Academy addresses *socialization* through several avenues. For example, the knowledge capture interviews and the courses delivered on college campuses epitomize the socialization pattern. The tacit knowledge is conveyed by how the TFs communicate rather than purely by what has been said. The TFs convey their values and enthusiasm to anyone paying attention, passing on lessons learned, perspectives on NASA culture (often tacit) and other important understandings, to the Academy staff. The staff in turn translates it into the curriculum as externalization or conversion of acquired tacit knowledge into specifications as discussed below.

This first step, however, is tacit-to-tacit learning or acquiring someone else's tacit knowledge through observation, imitation and practice. Here are some examples of how this has occurred within the Academy:

1. This definitely occurs in the classroom. Students are pleased to be able to have the opportunity to listen to, observe, and interact one-on-one with some of NASA's most prominent engineers. They also come to understand the passion that the TFs feel for their discipline.

2. Students also learn from each other in exercises and are then able to get feedback on their ideas from the TF. They share their own experiences and stories with the TF and fellow students, which allows each to glean a better understanding of an existing knowledge, or form a new tacit knowledge.

3. In addition, there is a transfer of information between the TF and graphic artists and animators as they attempt to depict incidents and circumstances, including events that have no other historical capture or record. Grasping the tacit knowledge is perhaps the most difficult because at times, the engineers do not understand or value elements of their own know-how. Often they will claim not to be an expert but simply a facilitator for other smart people.

Externalization has been adopted as a methodology for the Academy also; it happens when tacit knowledge becomes explicit. Much of the energy of the Academy staff is spent in capturing tacit knowledge and making it explicit.

1. TFs share their stories with the Academy instructional designers and SMEs through questions and answers that are recorded and transcribed.

2. That content is captured in a participant guide and distributed to every student, thus finding its way to publication in traditional print media and in slides as well as online. Despite clearly impressive experience, some of these engineers may not have had the luxury of publishing previously, and this is their first opportunity to put some of their ideas in print. The publications often have greater content than the actual classroom presentation. Classrooms are limited to approximately 30 students and questions are encouraged. Instructors use storytelling to get their message across. All students walk away with a manual covering the key points of the course as well as important stories, but they also walk away with knowledge of the online database.

3. The media elements—drawings, charts, photos, animations and diagrams—communicate to students in many ways. Furthermore, all of the documents, transcripts, photos, articles, diagrams, and artifacts provided by the TFs are captured in an online, searchable database.

When the information finds its way into the database, this might be characterized as *combination*—where explicit knowledge is converted to explicit knowledge, or combining discrete pieces of explicit knowledge forms new explicit knowledge. The Academy staff has taken the explicit knowledge from the platform classroom delivery and created an online version of the course with video, audio, and graphic images.

This is where technology particularly shines. The NESC Academy conducts its operations from an extensive Web site where users will encounter graphics, diagrams, photographs, formerly published articles, transcripts, charts, and even videos from the course deliveries. There is a searchable database that includes a vast store of information beyond that which was delivered in the classroom. Much of the material must be edited, keyword coded, and processed so that it is useful to the researcher.

Internalization, or internalizing explicit knowledge, occurs when people interact with the explicit knowledge they've learned and make it their own in that they come to have a new understanding intuitively—not even knowing how they gained it or where it came from.

That is, they turn explicit knowledge into tacit knowledge. Part of this happens when students recognize that they can learn valuable lessons from the past. Some of them learn how a discipline must interact with their own. Sometimes this occurs as learners decide to adopt some of the values of the older work force.

The cycle begins again as communities of practice, energized through internalization, start the sharing process again and pass information on to others, one on one, tacit to tacit.

Given these descriptions of the four patterns, we offer you these comments from the student surveys that show aspects of all four patterns in process.

A Propulsion course student said, “The information and insight that I was able to gain from these instructors is really valuable to a young engineer about to start his career. I would like to thank everyone involved in helping this program run. This program is an excellent tool that can be used to train and teach future engineers about what engineering really is and how one approaches engineering problems.” We can definitely see that socialization and externalization has occurred.

Another Propulsion course student wrote, “Offer this course more! Knowledge/experience learned here *has* to be passed on to those developing the CLV/CEV!” This comment seems to indicate that some internalization has or is occurring as the student has mulled over the CLV/CEV relationship to the lessons learned from the past.

“The lessons learned in several areas were very useful in gaining insight into potential problems when devising a system,” wrote a student from the Satellite Attitude Control Systems course. Is this an indication of the combination pattern? It appears that the explicit knowledge gained will be provided through some vehicle to others in designing a new system.

And yes, what about us—the authors and presenters of this topic? Definitely *we* have experienced aspects of all four patterns. We provide this to you in this example through both externalization and combination patterns. We have provided you tacit and explicit information about our knowledge, not only in the explicit form of a paper and presentation, but also through our sharing of knowledge. It is our hope you will experience both the socialization and internalization patterns, as we know we will.

Biographies

Dr. Marcia R. Gibson has substantial experience managing educational and training programs for federal, state, local, and private industry organizations. Her experience covers a breadth of skills: Distributed Learning Media, Curriculum Development, Marketing, Budget Development, Contract and Project Management, Personnel and Program Management, Human Performance Technology, and Leadership. She has developed training/educational policy and programs to support career field reconfigurations throughout her career. Currently, Dr. Gibson works for National Institute of Aerospace (NIA) and is the NASA Engineering and Safety Center (NESC) Academy Program Director. She has created the Academy and provides management of its curriculum development, knowledge management, and course delivery processes.

Terresita Alston, MSEd joined CIBER in 1997 and holds a master's degree in human resource management and a bachelor's degree in education with a training specialist emphasis. Her twelve years of experience in the training field includes curriculum design and development, WBT, facilitation, stand-up training delivery, computer-based training programming, courseware repurposing and multimedia design. Currently, Ms. Alston is the project manager for the multimillion dollar NESC Academy knowledge management project. She served as task manager and instructional designer for numerous courses for the Centers for Medicare and Medicaid, National Fire Administration (NFA), and several distance learning efforts.

Robert Leland Baxter, EdD has over 20 years of experience in the performance technology field, having been a project manager for dozens of government analysis, design, development, and training support tasks. Dr. Baxter provides oversight for development of the NESC Academy for CIBER, as well as custom performance projects for Health and Human Services and Navy strategic submarine programs. Dr. Baxter created the design strategy and participated in the interviews for the initial knowledge capture for the NESC Academy effort and contributes to the ongoing management and quality control of the project. Dr. Baxter was prepared as a historian and conducted many elite interviews as part of his dissertation research. His doctorate was earned from the University of Virginia in higher education administration with minors in business and counselor education. Dr. Baxter served as an Assistant Dean for that University and as a past director of the Federal Educational Technology Association.

Nonaka, I. & Takeuchi, H. (1995). *The knowledge creating company: How Japanese companies create the dynamics of innovation.* Oxford University Press.

Polanyi, M. (1966), "The Tacit Dimension, London :Routledge & Kegan Paul.